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Farmers' Guide in Concrete Construction

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IN
CONCRETE CONSTRUCTION

BY

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WILLIAM WALTER SMITH

ENTITLED FARMERS' GUIDE IN CONCRETE CONSTRUCTION

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF BACHELOR OF SCIENCE IN CIVIL ENGINEERING

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FARMERS' GUIDE IN CONCRETE CONSTRUCTION.

PART I.

THE CONCRETE: ITS COMPOSITION, MIXING AND PLACING.

INTRODUCTION.

The present and prospective price of lumber is so high that economy in building demands the use of as little wood as possible. Other materials are being substituted for wood, and chief among them is concrete.

The wide distribution and unlimited quantities of sand, gravel, stone and materials for cement make concrete construction available everywhere. Cement factories are multiplying and their product will become cheaper. Concrete construction is permanent; and the farmer of to-day, no longer a pioneer, need not look so much to cheapness of first cost as to the value of permanency.

This thesis is written presumably for the farmer,-a man skillful in his own profession, but naturally not an expert architect, carpenter, or mason. It is the purpose to afford plain, practical guidance in simple concrete construction. Theory and technical terms are purposely avoided.

THE PERFECT CONCRETE.

The perfect concrete would consist of a mass of material, called the aggregate,varying in size from two or three-inch gravel or stone to the finest sand,and the whole so graded and proportioned that the spaces between the successive sizes,called the voids,would be filled with the largest particles which would fit into them. This would allow a minimum coating of cement to act as filler and binder; and,since cement is the weakest component of good concrete, this minimum coating of cement would produce a concrete of the maximum strength and of the minimum cost.

The perfect concrete is unobtainable; yet,by careful selection and treatment of materials,results may be obtained which closely approach the ideal.

SELECTION OF THE AGGREGATE.

SAND.

Coarseness and cleanness are the most important qualities of sand for concrete. Coarse sand is generally clean and dense, and therefore produces a denser and stronger concrete than fine, light sand. Drift sand makes very weak concrete.

Dirty sand weakens the mortar and often delays its setting. The blame is usually cast upon the cement,but it is more frequently due to bad sand. To test the cleanness of sand,rub a small bit in the palm of the hand; if the hand is practically unsoiled the sand is clean. Either wet or dry sand may be tested for cleanness by filling a fruit jar about one quarter full of sand and adding water until the vessel is three quarters full. Shake well,and allow the water to settle for a couple of hours; then if a considerable

layer of sediment is deposited,the sand should not be used without washing.

Sticks,leaves,and gravel (if necessary) may be removed by screening. Loam and clay can be washed out either on a wire screen or in an inclined,V-shaped,wooden trough. Where water pressure is to be had,a hose will be of great advantage.

A small amount of clay in sand,10 to 15%,does not injure it for use in cement mortar,provided the clay is not in lumps. In fact for mixtures lean in cement,the clay seems to add strength.

GRAVEL.

Gravel should be clean so that the cement may adhere to it completely and tightly. The largest stone allowable in concrete is somewhat dependent upon the use to which the concrete is put. Where the concrete can be well tamped,a few stones three or even four inches in diameter may be used. (See DEPOSITING.)

Screening. For ordinary work sufficiently good results can be obtained from bank-run gravel; yet experience has shown that the proportion of sand and stone varies considerable even in a single bank. This lack of uniformity necessitates an excess of cement to insure a well bound concrete.

On first consideration screening and proper remixing of gravel and sand seem to be an additional trouble and expense; but by so doing a stronger concrete is secured and much less cement is used. All particles below one quarter of an inch may be considered as sand. For most purposes there should be one part sand to two or two and one half parts pebbles.

BROKEN STONE.

The best stone is one which is clean,hard,breaks with a

sharp angular fracture,and to which the mortar easily adheres. The maximum size is dependent upon the nature of the work. (See DEPOSITING.) Broken stone should never be screened further than to remove the dust,as the small particles are not a detriment but a decided advantage. They reduce the amount of required cement and add additional density and strength to the concrete. However,in proportioning,the smaller particles,say below one quarter inch,must be considered as sand and precaution must be taken to secure their uniform distribution.

Kind of Stone. The value of stone for concrete depends upon its toughness and hardness. Trap,granite,limestone are good; but the use of shale,slate,and very soft limestones and sandstones should be avoided.

CINDERS.

Cinders are exceedingly valuable for concrete where small strength is allowable and little weight desirable. Only hard and thoroughly burned cinders should be used; and,to remove the dust, these should be thoroughly screened. Cinder concrete is a poor conductor of heat and therefore a good fire-proofing.

BROKEN BRICK.

Broken brick is coming into use for making concrete. Choice of brick is governed in the same way as that of stone. (The harder building and paving brick make the strongest concrete.) Great care must be exercised to remove the dust caused by the breaking.

CEMENT.

There are two general classes of cement,Natural and Portland. Portland cement is a carefully proportioned manufactured product. It is therefore more reliable and so much greater in

strength that it gives better results at less cost than Natural cement. Hereafter all references to cement mean the Portland variety only.

Selection. The scientific tests of cements are both too intricate and too expensive for the small consumer. In selecting a cement he can do nothing wiser and better than to choose some standard brand of Portland which has been on the market for several years,and which is and has been used successfully on important constructions. On such work many careful tests are made on each shipment.

American cements are equally as good and cost much less than the foreign product.

Cost. A few sacks of cement will naturally cost more proportionately than a car load. Where large quantities will be required,it may pay the consumer to purchase it wholesale,provided he purchase some brand not carried by local dealers. At the present time (1907) in central Illinois the well established brands of cement sell for $1.80 per barrel in car load lots. Four sacks of 94 lbs. net constitute a barrel of 376 lbs. net.

Storing. Cement must be kept in the dry upon a floor well clear of the ground and out of danger of driving rain.

WATER.

Nearly any good-tasting drinking water is suitable for making concrete.

MIXING BOARD.

The mixing board should be solidly and tightly constructed and located as near the work as possible. A level platform 8 x 14 feet,built of two-inch or two thicknesses of one-inch

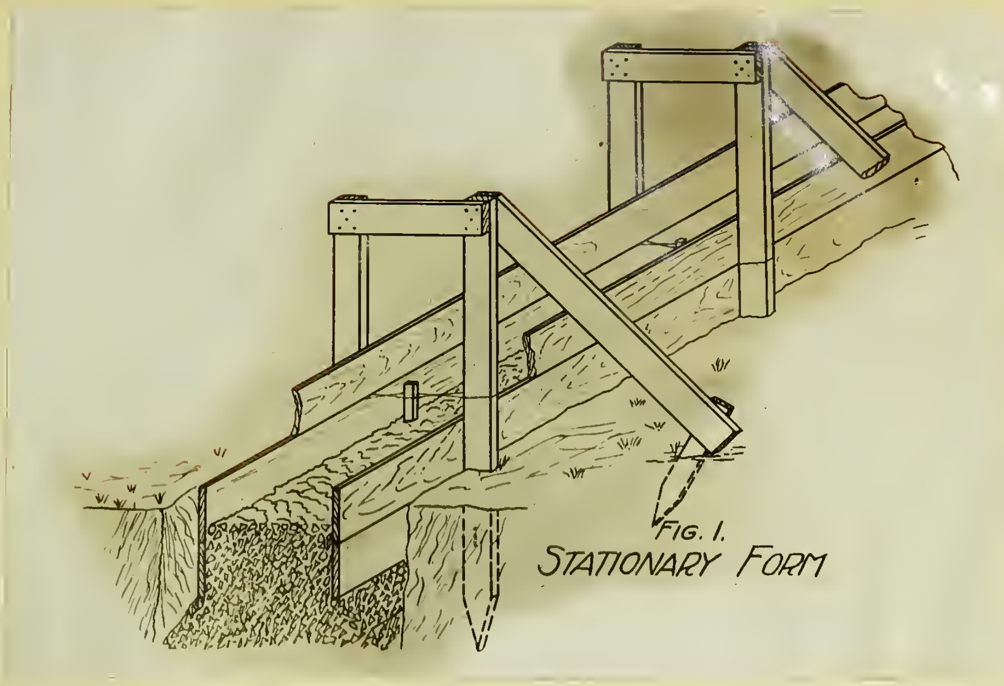
material,will be suitable. A larger platform 14 x 14 feet will accomodate two batches and thereby allow continuous mixing and placing.

THE FORMS.

Seasoned lumber,although not quite so good in some respects as green,must usually be used as sheathing in the construction of the forms. Boards dressed on one side and with close fitting edges give the neatest appearing finish to the surface of the concrete. In very particular work tongue-and-grooved or ship-lap lumber is used. Seasoned lumber,affected by the wet concrete, will sometimes buckle if the cracks between the planks are drawn too tightly.

Stationary Forms. The most common style and the best adapted to small work is the box-like stationary form. Sheathing of 1 to 2-inch lumber is lightly nailed to the inside of the vertical studding. (The best boards should be used where the surface of the finished concrete will be exposed to view.) The size and spacing of the studding is dependent upon the height and the width of the wall,and the manner of bracing. For ordinary work such as barn foundations and cellar walls,where 1-inch sheathing is used 2 x 4-inch scantlings are spaced 2 to 3 feet; and with 2-inch siding 2 x 6-inch uprights may be placed at intervals of 5 to 6 feet. Bellying of sheathing and studding may be easily and cheaply prevented by wire ties as shown in Fig. 1.

Movable Forms. The amount of lumber demanded by work of considerable extent for stationary forms renders the cost of concrete excessive. Consequently the movable form has been adopted,which allows the same lumber to be used several times on the same structure.



Movable forms are of many designs, yet the underlying principle of all is the same. Concrete is placed in layers until the forms are full, say to the depth of 4 feet. After all the concrete has set for at least 12 hours, the forms are loosened, moved up, and put in readiness for receiving another addition to the concrete wall.

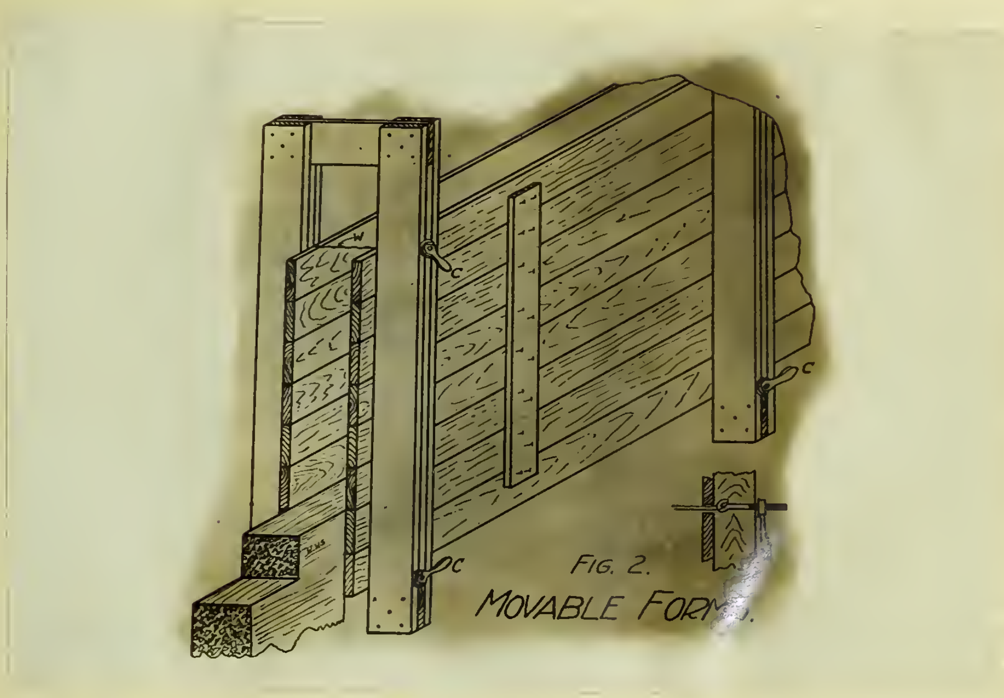


Fig. 2. represents a simple and effective type of this style of form. With the form full of 12-hour old concrete, the crank nuts

(c) of all the ties are loosened,the lower two so much that their hook-shaped bolts may be removed from the loops of the wire ties (w) and the slotted standards are shoved up in readiness for receiving the sheathing. Note that the form has a purchase of one fourth of its total height on the set concrete. This hold serves as a guide in keeping the walls plumb.

After the forms are moved up the projecting wire loops may be cut off and the holes filled with facing mortar.

Circular Forms. Circular forms may be easily constructed by laying a circle of the desired size upon a floor or level ground. Upon this circle place lengths of boards as shown in Fig. 3. Tack them lightly together,and then with the same center draw a circle upon the boards. Saw along the circular line and join pieces as indicated.

To secure the desired inside diameter of the structure,construct the inner form with a radius equal to one half the intended clear diameter less the thickness of one side of the sheathing. Likewise the circle of the outer form is laid out with the radius equal to the desired radius in the clear plus the thickness of one

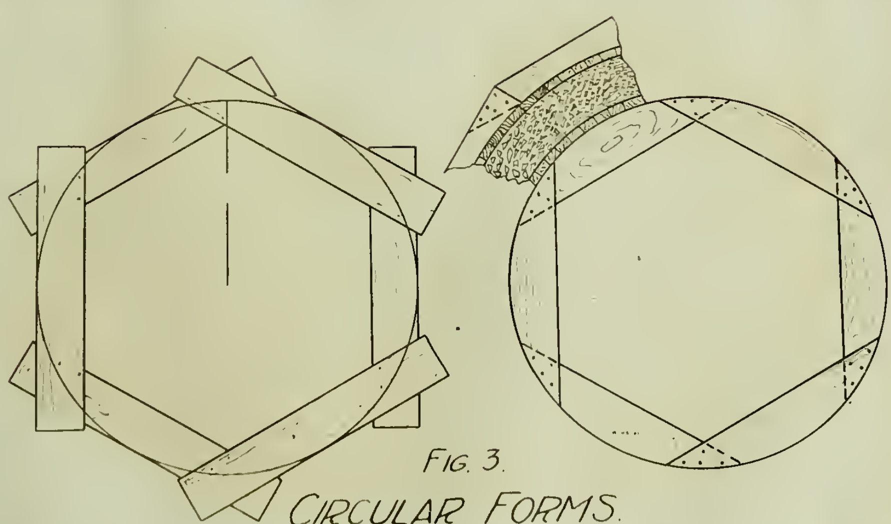


FIG. 3.
CIRCULAR FORMS.

side of the sheathing. Iron hoops or bands with clamp attachment for tightening may be used in place of the circular board bracing. Sometimes thin sheet iron is substituted for the wooden sheathing. The forms may be either stationary or movable. (See MOVABLE FORMS,page 6.)

Oiling Forms. In very particular work the faces of the forms may be oiled so that small particles of concrete will not be detached on removal of the forms. Soap or crude petroleum will do. With metallic forms the best results are obtained from fat salt pork.

Corners. As it is difficult to obtain perfect projecting corners of concrete,unsightly ones are frequently avoided by tacking triangular strips in the corners of the forms.

MIXING CONCRETE.

The Proportions. Not all construction demands the strongest concrete; yet so much experience is necessary to determine the correct proportions for a desired strength that it is safest to use that mixture only which gives the greatest strength. Many ways of determining this proportion have been devised,- some methods are very accurate and all more or less intricate. The methods are based on the voids or unfilled spaces in the sand,gravel and stone. Voids in sand usually run about 30%,gravel 30 to 40% and broken stone 30 to 45%. Variations in the sizes of the material may affect proportions based on these voids as much as 10% either way, yet such variation will produce no appreciable effect on the strength of concrete used in ordinary work.

Proportions designated by numerals,say 1:3:6,mean 1 part cement,3 of sand and 6 of gravel or stone. In this thesis these parts will be determined by volume.

In the following table is given the safe working strength of concrete in direct compression after the concrete has set for one month.

TABLE I.

SAFE STRENGTH OF CONCRETE IN DIRECT COMPRESSION.

Proportions.	Kind of Mixture.	Pounds per Square Inch.	Tons per Square Foot.
1 : 2 : 4	Rich	410	29.5
1 : 2 1/2 : 5	Medium	360	25.9
1 : 3 : 6	Low	325	23.4
1 : 4 : 8	Lean	260	18.5

The Rich Mixture.is well suited to engine foundations,extremely heavy loading,and tanks and other water-tight constructions.

The Medium Mixture is well adaptable to most ordinary work such as foundations,walls of buildings and sidewalks.

The Low Mixture is strong enough for heavy walls and abutments.

The Lean Mixture is sufficiently good for work in which strength is not such an important factor.

TABLE II.

QUANTITIES OF MATERIALS FOR ONE CUBIC YARD OF RAMMED CONCRETE, BASED ON A BARREL OF 3.8 Cu. FT.

Proportion By Parts.			Proportion By Volume.			Percentage of Voids in Broken Stone or Gravel. 50%			45%			40%			30%			20%		
Cement.	Sand.	Stone.	Packed Cement.	Loose Sand.	Loose Stone, Gravl.	Cement.	Sand.	Stone.	Cement.	Sand.	Stone.	Cement.	Sand.	Stone.	Cement.	Sand.	Stone.	Cement.	Sand.	Stone.
			Sacks.	Cu.Ft.	Cu.Ft.	Sks.	Cu.Yd.	Cu.Yd.	Sks.	Cu.Yd.	Cu.Yd.	Sks.	Cu.Yd.	Cu.Yd.	Sks.	Cu.Yd.	Cu.Yd.	Sks.	Cu.Yd.	Cu.Yd.
1	2	4	4	7.6	15.2	6.6	0.46	0.93	6.3	0.44	0.88	6.0	0.42	0.84	5.5	0.39	0.78	5.1	0.36	0.72
1	2½	5	4	9.5	19.0	5.5	0.48	0.96	5.2	0.46	0.92	5.0	0.44	0.87	4.5	0.40	0.80	4.2	0.37	0.73
1	3	6	4	11.4	22.8	4.6	0.49	0.98	4.4	0.47	0.94	4.2	0.44	0.89	3.8	0.41	0.81	3.5	6.37	0.74
1	4	8	4	15.2	30.4	3.6	0.51	1.01	3.4	0.48	0.96	3.2	0.46	0.91	3.0	0.42	0.83	2.7	0.38	0.77

TABLE III.

AVERAGE VOLUME OF RAMMED CONCRETE MADE FROM ONE BARREL (4 SACKS) OF PORTLAND CEMENT.

			Cu.FT.	Cu.Ft.	Cu.Ft.	Cu.Ft.	Cu.Ft.
1	2	4	16.3	17.2	18.0	19.6	21.3
1	2½	5	19.8	20.8	21.8	23.9	25.9
1	3	6	23.2	24.4	25.6	28.1	30.6
1	4	8	30.0	31.7	33.3	36.6	39.9

For Table III the % of Voids is the Same as the Corresponding Columns of Table II.

See Important Foot Notes on Page 1[illegible].

Note.- (1) Variations in the fineness of the sand and the compacting of the concrete may effect the volume 10% in either direction.

(2) Use 50% column for broken stone screened to uniform size.

(3). Use 45% column for average conditions and for broken stone with dust screened out.

(4) Use 40% column for unscreened or mixed stone or gravel.

(5) Use these columns for scientifically graded mixtures.

The Measuring. A convenient unit of measurement is the dish-shaped iron or wooden wheelbarrow. This barrow may be easily gaged by means of a bottomless box 12 x 14 3/8 x 10 inches, inside measurements, which has a volume of one cubic foot. Each inch of height of the 10 inches is equivalent to one tenth of a cubic foot.

The cement should be used by the bag or bags and the other materials measured to correspond. It is very poor practice to measure by counting the shovelfuls.

Quantity of Water. The proper quantity of water is dependent upon the rapidity with which the concrete is desired to set. Dry concrete sets more quickly than wet, but the wet finally attains the greater strength. A very safe mean is that concrete which, when tamped in place, shows a thin layer of floating cement.

The Mixing. Having determined the best proportion for the proposed work, the proper quantity of sand is spread out in an oblong shape upon the mixing board, and upon this is distributed the full amount of cement. (When less than four men are doing the mixing, wheeling and placing, two sacks of cement will usually yield all the concrete that can be handled before setting commences.) Two men, opposite each other and at one end of the batch (and if necessary two at the other end), with square pointed "paddy" shovels, turn the sand and cement with a flopping, dragging stroke. By

timing their strokes,the shovels will meet at the middle,and perfect turning will result.

The stone,previously wet in the wheelbarrow,or the screened gravel,is spread upon the mixture and the whole is wet with water from a bucket with a sprinkler attachment or from a hose with a spray nozzle. (Water dashed on from the ordinary bucket or hose washes away the cement.) After the concrete is turned over once,water is again added,this time in sufficient quantity. The concrete is given a final turning and then thrown into a ridge ready to be wheeled away.

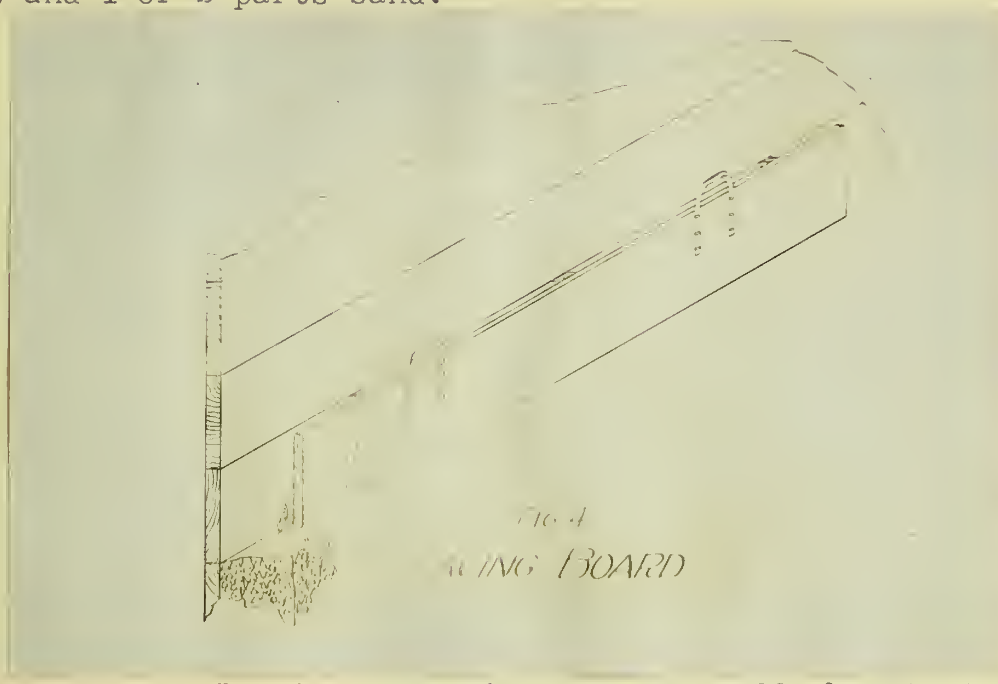
Unscreened Gravel. One half of the necessary amount of gravel is spread in the manner before-mentioned. Upon this is distributed the cement and then the remainder of the gravel. The entire mass is turned dry until well mixed,then wet and treated as stone concrete.

Depositing. The wheelbarrows are very useful in transferring the green concrete from the mixing board to the forms. If the forms are wide enough,the concrete may be dumped directly into them; but poor results are likely to be attained if the concrete is dropped further than 8 or 10 feet. It should never be slid down troughs,as the larger particles move more rapidly and fall to the further side of the form and clear of the cement mortar. The best workmen seldom deposite concrete in layers thicker than 8 or thinner than 4 inches. Each layer should be brought level with a spade (a crack in the forms is a good guide),and then where the

Facing. concrete will be exposed to view,the spade should be run down between the green concrete and the wall of the form and worked back and forth perpendicular to the form. This operation forces the stone back from the form; the mortar flows in and produces a

smooth,solid surface,free from unsightly stone.

As workmen will not always do the spading well,it is sometimes better to use the iron or wooden facing board. (See Fig. 4.) These are set up against the wall previous to the placing of the concrete,and,after that operation,the space between the facing board and the wall is filled with a mortar consisting of 1 part cement and 1 or 2 parts sand.



Importance of Tamping. Tamping not only adds beauty to the appearance of the wall but also renders the concrete more nearly water tight and increases the strength often as much as 50%.

Waterproofing. Numerous waterproofing compounds,of more or less value,are on the market. However sufficiently good results for most purposes may be obtained by using a 1 : 2 : 4 concrete wet to the consistency of quaking,well puddled with a small scantling,and supplemented with a facing mixture of 1 : 2 mortar. See FACING, page 13.)

Finishing. It is poor practice to plaster set concrete walls with a facing mortar,as the mortar nearly always scales off and produces an ugly appearance. For the finishing of top surfaces see

SIDEWALKS.

Protection Against Freezing. It is doubtless best to avoid laying concrete in freezing weather. The alternate freezing and thawing of green concrete injures it seriously. However,when work must be done in cold weather,hot water may be used in the mixing and the placed concrete covered with a tarpaulin,old carpet,straw, or,better still,fresh strawy horse manure. Care must be exercised in using manure,as it sometimes stains the concrete.

Protection Against Hot Sunshine. Green concrete exposed to hot sunshine will develop small unsightly cracks. Ordinary work,such as small foundations,should be protected 24 to 48 hours. For a treatment of more particular work,see SIDEWALKS.

REINFORCED CONCRETE.

The subject of reinforced concrete is too technical to come under the consideration of this article. In the construction of concrete buildings,the scientific use of steel may often reduce the cost and be of other advantages; but the unscientific guessing methods,so often used,endanger life and cause unnecessary expense. For all structures needing reinforcing consult a practicing architect or engineer who has a reputation in this line of work.

PART II.

PLANS FOR VARIOUS CONCRETE STRUCTURES.

FOUNDATIONS.

General Instructions. The compressive strength of well made concrete foundation walls at the age of one month may be safely considered as twice that of brick walls; that is to say, buildings requiring a 12-inch wall of brick can be supported by a 6-inch wall of concrete. However the foundation wall should never be thinner than the walls or sills of the superstructure, and should always have a spread base as shown in Fig. 2.

Upon concluding the day's work, step off the concrete as shown in Fig. 2; and, upon resuming, scrub the exposed surface and, unless the concrete is very rich and wet, coat with a thin 1 : 1 cement mortar.

The Excavation. The depth to which excavation must be carried is dependent upon the bearing power of the earth, the height of the foundation wall, and climatic conditions. In some sections of the country foundations should be carried below the frost limit; and they ought never be less than two feet below the surface of the ground. Foundation walls of considerable height and with light loading need not go to the frost limit, as the wall itself acts as a continuous beam. The trenches are dug several inches wider than the intended wall to give space for the studding of the forms. By allowing the concrete to protrude under the sheathing (see Fig. 2) of the forms additional bearing is attained.

Barn and Crib Foundations. Foundations for barns, cribs, granaries, etc., are seldom made less than 6 inches thick. (See

GENERAL INSTRUCTIONS, also FORMS, pages 16 and 6.) The forms may be removed after the concrete has become so set (12 to 24 hours) as not to be indented by the pressure of the thumb. Light framing may be started after the walls are one week old, but heavy loading should not be imposed, if avoidable, until one month has elapsed. (See FACING, page 13, and TAMPING, page 14.)

Cellar Walls. The minimum thickness of cellar walls is usually 8 inches. The earth, if it is firm, may be utilized as the back walls of the forms for receiving the concrete. Use the 1 : 2 : 4 mixture in the manner designated under WATERPROOFING, page 14.

Pillars. On account of the overturning tendency of pillars, good judgement must be exercised in deciding their height and size, and especially must particular care be given to the exact centering of the load. Excavate the hole considerably larger than the base of the form and cover the bottom with a suitable thickness of concrete. Make the base of the form larger than the desired size of the top, so that all sides may have a slope of 1 to 2 inches to the foot. The top of the pillar should project beyond the load not less than 2 inches in all directions. Wooden uprights may be more securely attached to pillars by setting a bolt in the center of the pillar corresponding to a hole centrally located in the timber.

CISTERNS.

Cisterns are made either circular or rectangular in shape. The round kind requires the less material, but the other is by far the more easily built. For circular cisterns the greatest capacity for the least amount of concrete is obtained when the depth is equal to the diameter of the circle. Of the rectangular shapes the cube is the most economical; therefore, for this style, the depth, length and breadth are equal.

Where the earth will stand of itself, make the dimensions of the excavation equal to the clear dimension desired plus twice the thickness of the wall. If an outer form must be used, the additional width thus demanded must be taken into consideration.

Use a 1 : 2 : 4 concrete in the manner designated under WATERPROOFING, page 14. After the hole is excavated and all loose earth removed from the bottom, place the forms. Then lay a 5 1/2-inch floor and follow immediately with a 1/2-inch trowel-finish 1 : 2 mortar. Proceed quickly with the wall and carefully make all joints between floor and wall waterproof. Walls are seldom less than 6 inches in thickness and constructed according to FORMS, page 6.

TABLE IV.

CAPACITY OF CISTERNS.

(1 Barrel = 31.5 Gallons = 4.21 Cubic Feet.)

Circular.		Cubical.	
Diameter = Depth.	Barrels.	Height=Width=Depth.	Barrels.
5 Feet	23.3	5 Feet	29.7
6 "	40.3	6 "	51.3
7 "	64.0	7 "	81.4
8 "	95.5	7.5 "	100.1
9 "	136.0	8 "	121.5
10 "	186.5	9 "	173.0

WALKS AND FLOORS.

Sidewalks. The successful construction of concrete sidewalks is by no means an easy task; yet, through a careful attention to details, even an unskilled workman may obtain good results.

The Excavation. The excavation should be made three inches

wider, on each side, than the width of the desired walk and to the depth determined by the total thickness of the foundation, the base and the wearing surface. All roots of trees should be removed and the bottom of the trench well tamped.

The Foundation. The foundation is as important in walks as in more pretentious structures. It consists of a mass of well wetted and rammed crushed stone, gravel, coarse sand or cinders, and varies in thickness from twelve inches in cold northern United States to zero inches in warmer sandy sections. For ordinary conditions 4 inches of stone, 6 inches of gravel, or 8 inches of cinders or sand is sufficient.

Many walks are cracked by the freezing of water and its consequent upheaval. This may be easily prevented by the laying of drain tile (even blind drains) at points where water is liable to cause trouble.

The Base. The base consists of a layer of concrete which rests upon the foundation and supports the wearing surface. As no excessive strength will be demanded a 4-inch layer of 1:2 1/2:5 concrete will suffice.

The Wearing Surface. The wearing surface consists of a 1-inch thickness of a 1:2 or a 2:3 cement sand mortar. To give the walk a uniform color, the materials should be measured very accurately. Sufficient water should be used to bring the mortar to that degree of stiffness commonly used by masons in laying brick.

The maximum thickness of the wearing surface is one inch, and, if the wear is not great and the base has been carefully leveled, this thickness may be reduced to one half inch.

The Construction of the Walk. After the excavation and foundation have been completed in the manner described above, the forms for the

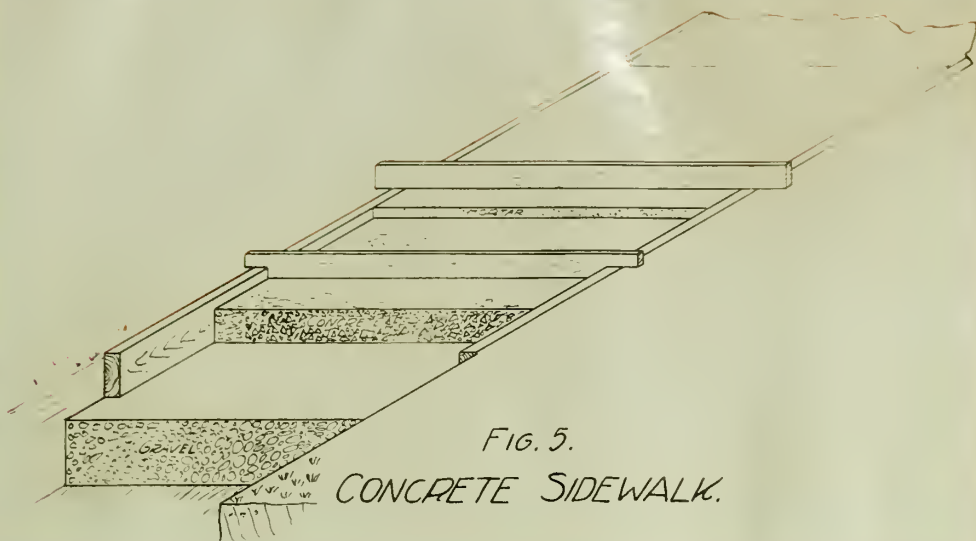


FIG. 5.
CONCRETE SIDEWALK.

walk are placed. These forms consist of 2 x 4-inch or 2 x 6-inch scantlings, sized and dressed at least upon the inner side and the upper edge. The scantlings are lightly but securely nailed to strong stakes set at four to six feet apart, previously lined in and leveled exactly to the finished surface of the walk. Upon the upper edge of the forms and directly opposite are made permanent marks as guides for dividing the walk into blocks of the desired size. These blocks are usually not quite as long as the walk is wide; i.e., 3 x 4 feet. If the walk has insufficient slant to drain itself longitudinally, it is well to make a slope crosswise of one fourth inch for each foot of width.

The concrete for the base is mixed in accordance with the method previously given (See MIXING, page 12.). Enough water is used to bring the concrete nearly to the consistency of quaking. Prior to the mixing, the foundation is well wetted and upon this the concrete is deposited and tamped. In tamping care must be taken not to disturb the forms. By means of a straight edge, the base is brought to a level at the height at which the wearing surface begins.

A convenient straight edge consists of a board so made that its shoulders will slide along the top of the forms and deep enough that its lower edge will extend to the desired upper surface of the base.

By means of a spade and a straight edge the concrete is now cut through to the foundation into blocks of the approved size. This cleft should then be filled with clean sand. By so dividing walks,cracks due to temperature and to roots of trees are confined to these joints. (Some builders accomplish the same result by placing a thin steel plate across the forms and removing the same after the second block is in place. Others,by the use of a cross board,build the block alternately; and the same day after the wearing surface has stiffened,complete the walk.)

When a block of the base is finished,it is of the utmost importance to follow immediately with the wearing surface so that the two layers may set as one. The mortar,after it has been well worked with a light rammer,is brought to a level by the repeated use of a straight edge. When the resulting film of water is nearly absorbed the surface should be worked with a wooden float. If a smoother finish is desired,this operation may be followed by troweling with a plasterer's trowel; however such a finish renders a walk more slippery than is generably desirable. The top dressing should not be worked too long as excessive troweling brings surplus cement to the top and later produces scaling.

By means of a trowel guided by a straight edge the wearing surface is now cut through exactly over the joints in the base, after which the corners are rounded off with a special tool called a jointer. The rounded edges on the outside of the walk are obtained by another special tool,the edger.

The completed walk should be protected from the tread of animals and from hot sunshine. The surface should be kept moist, and, after say twenty-four hours, this may be accomplished by the use of a layer of sand, which should be moistened as needed with a sprinkler or with a spray nozzle. If possible, keep the walk out of use until it is one week old. (See PROTECTION AGAINST FREEZING, page 15.)

BARN FLOORS.

Barn floors are laid in the same manner as sidewalks. However the foundation should be a little thicker; and the wearing surface, since it will be grooved or roughened, should not be thinner than 1 inch. Sufficient slope must be given the floor to permit the escape of liquids into open or closed gutters or into tile laid with cement joints in the foundation. Provision should be made for cleaning the gutter or tile, and all covers should be sunk 1/4 inch below the surface of the floor.

WELL PLATFORMS.

Construct well and cistern platforms in practically the same way as one block of the BASE and the WEARING SURFACE of SIDEWALKS. As platforms are usually built in place (unless small), forms consisting of a tight and well-supported wooden floor and of side boards are necessary. Upon this bottom tack frames of the size of the desired openings. Tamp in 3/4 inch of concrete and upon this stretch heavy woven-wire fencing. Continue the placing of the concrete until it is 4 to 6 inches thick, the thickness depending upon the dimensions of the unsupported platform. Finish according to SIDEWALKS, page 18.

CELLAR FLOORS.

As there is no danger of frost,cellar floors may be made without a foundation. Expansion joints will not be needed unless the floor is to be subjected to extremes of temperatures. For the manner of construction consult SIDEWALKS,page 18. To insure an uniform thickness scantlings may be placed 10 to 12 feet apart as guides for a straight edge. These may be withdrawn later and the space filled with concrete.

CORN CRIB FLOORS.

With slight modifications corn crib floors may be constructed in the same manner as side walks. The floor should slope either from the center to both sides or toward the weather side of the crib. Iron straps bent at a right angle and imbedded in the concrete are convenient fasteners for wooden uprights. Before imbedding,straps on opposite sides should be tied together with wire.

FEEDING FLOORS.

Feeding floors are made in the same way as sidewalks. Many stockmen prefer to use no cement-mortar wearing surface,as the rough concrete affords a better footing. The wearing surface offers the advantage of easy cleaning. It may be roughened in the same manner as driveways. A slight slope to one side will facilitate drainage.

CURB AND GUTTER.

Local conditions largely determine the dimensions of curbs and gutters. Fig. 6 clearly illustrates the method of constructing a combined curb and gutter suitable for a gravel, cinder or broken-stone drive.

The construction is much like that of sidewalks. The foundation of cinders or gravel is well wetted and tamped. The back wall and the lower board of the front wall of the forms are then erected. The concrete for the base and the mortar wearing surface are laid-all before the upper board of the front form is set. Facing boards are now put in place and the concrete for the body of the curb is deposited and tamped. The space between the form and facing board is then filled with a 1:2 facing mortar,after which the facing boards are removed. When the mortar has set sufficiently to stand alone,the board in front of the curb is taken out and the curb and the gutter are troweled smooth. In order to remove the glaze or shine of the trowel finish,the face may be lightly brushed with a stiff,stubby paint brush.

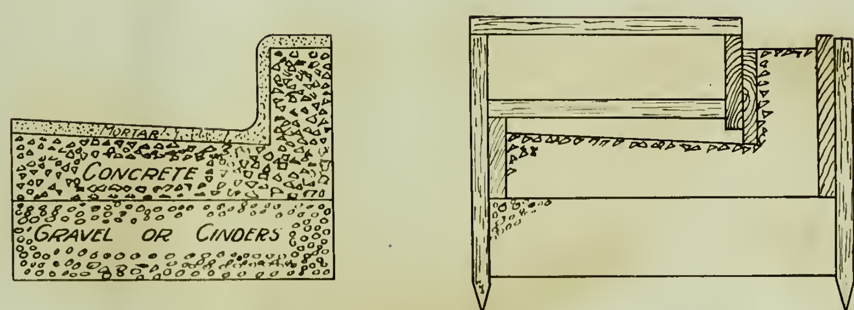


FIG. 6.
CURB AND GUTTER.

The curb may be constructed in alternate longitudinal sections 6 to 8 feet long; and,on filling in the remaining sections, expansion joints may be obtained by the use of heavy paper. A better alignment is secured by building the curb continuously and by using well-greased 1/8 or 3/16-inch sheet iron as a means of

effecting the expansion joint. These metallic plates are left in place until the troweling is finished. The curb should be protected from the sun and kept moist for several days.

The inward slope of the gutter surface toward the curb is not necessary for concrete driveways.

DRIVEWAYS.

The method of constructing driveways is similar to that of barn floors. Expansion joints should be put in as in sidewalks with one joint lengthwise in the middle of the driveway. With grooves 1/4-inch deep divide the surface into 4-inch squares,or roughen it with an indenting roller.

STEPS.

Steps of concrete may be constructed in separate moulds, or in place as one piece. The latter method is the easier and,on the whole,the more satisfactory. The construction of steps varies with local requirements,and the following plans,suitable for most conditions,may have to be altered for others.

Terrace Steps. If there is danger of freezing or if the depth to solid ground is too great,the excavation is carried down and a foundation placed as in sidewalks (See SIDEWALKS,THE FOUNDATION, page 19.). The total height of the terrace is then divided into rises of equal height,each division not less than 6 nor more than 8 inches. The surface of the step should be 10 to 12 inches wide from front to back for ordinary conditions and not less than 30 inches in width where the climber is supposed to make one stride upon each of the steps.

Steps are made with or without housing (closed ends). If steps with open ends are desired,one uncut board on each side will serve as a form for the ends of the steps. With housings,steps

are made a little wider than the walk so as not to look cramped. The inside form of the housings is cut as in Fig. 9A. The boards for the risers are 1/2 inch narrower than the height of the rise of each step and are lightly tacked to cleats nailed to the forms for the housings. They are so fastened that their upper edges are

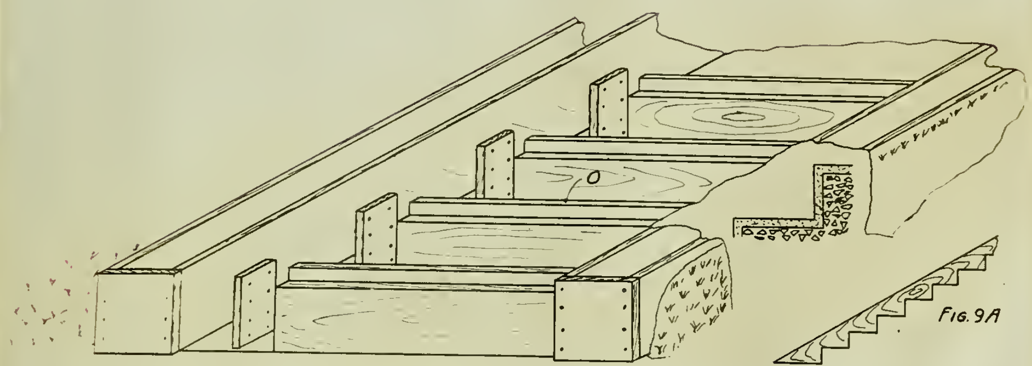


Fig. 9B

STEPS WITH HOUSINGS.

even with the finished surfaces of the steps and that their front faces are 1 inch from the finished rises. Into this 1-inch space is placed a loose well-greased board (O),at least 1 inch wider than the rise which will later be withdrawn and replaced with facing mortar. (See Fig. 9B.)

The concrete is of the same mixture as that of SIDEWALKS,but only sufficient water is used in the mixing to make the concrete a little more moist than damp earth. This will enable the concrete to quickly stand alone when well tamped. Begin placing the concrete at the top step and work downward. Use 1 inch of facing mortar for the top of the step; and,after removing the loose 1 inch board of the rise,fill this space also. Use ordinary facing boards for the housings. As soon as the facing mortar will stand alone,remove all forms and finish with a trowel. Protect as in SIDEWALKS.

A slight slope should be given the wearing surface of the steps to permit drainage. The nousings must be heavy enough to look proportionate.

Cellar Steps. Cellar steps are made in a manner very similar to that of TERRACE STEPS.

WATERING TROUGHS.

With the addition of an outside form, watering troughs are constructed in the same manner as cisterns. The rectangular shapes are more easily built than the circular. (See FORMS, pages 6 to 9.) Table IV, page 18, may be of some aid in determining the dimensions.

To build the tank, excavate to solid ground or to the depth desired and level off the bottom. Put in all necessary entry and overflow pipes and drainage tile. The overflow pipe should be in two sections with the shorter piece just long enough to be flush with the finished top of the bottom of the tank, which is usually 5 inches thick. Construct the outer form vertical. With an allowance of 4 inches for the top of the wall, as a safeguard against ice and stock, let the inner form slope toward the center of the tank two inches horizontally for each foot in height; e.g. a tank 2 feet deep will have a wall 4 inches thick at the top and 4 plus 2 x 2 = 8 inches at the base. A few pieces of heavy wire along the sides near the top will give additional strength. See REINFORCEMENT OF CONCRETE FENCE POSTS, page 28.

If a cover is desired, place bolts in the concrete during the building. Protect the concrete from the sun, sprinkle daily and allow the forms to stand for one week. Keep a guard rail along the top of the tank until the concrete is two months old.

CONCRETE FENCE POSTS.

General. On account of their resisting quality, both to decay and to fire, and the consequent cheapness due to their durability, concrete posts are rapidly coming into general use. The strength of wooden posts (when sound) is three to five times that of concrete posts, but the former are much stronger then necessary while the latter, when well designed, are sufficiently strong for the purpose and continually gain strength with their increasing age.

Reinforcement. To increase their strength concrete posts are reinforced with steel wire or rods. The size of a single wire (not necessarily galvanized) commonly used is No.6, 0.19 inches in diameter, or two No. 10 wires, 0.13 inches in diameter, twisted together. If a single rod is used, the ends should be bent over or looped to increase the bond between the metal and the concrete, and the total length should be a little shorter than that of the post. One reinforcing member 1 inch from either surface, in each corner of the post is doubtless the best arrangement.

The Concrete. For posts a 1:2 1/2:5 concrete has proved satisfactory. The gravel or broken stone should not exceed three quarters inch in diameter; and, to avoid much tamping, the mixture should be wet nearly to quaking.

The Rectangular Molds. Metal molds are used by some manufacturers but wooden molds, coated with soap, oil or shellac give very good results. Figures 7 and 8 show the plans of two molds, the one for posts with only two sides tapering and the other with four sides tapering. The siding (s) consists of a 2-inch material dressed on both sides, while the ends (e) are of 1-inch stuff to which are nailed the lugs (l). The siding is inserted between the lugs. The molds are held together by means of hooks and eyes

(h). If the siding tends to bulge, it may be made more rigid by means of a tie (t). Notice that in Fig. 7 the posts are molded

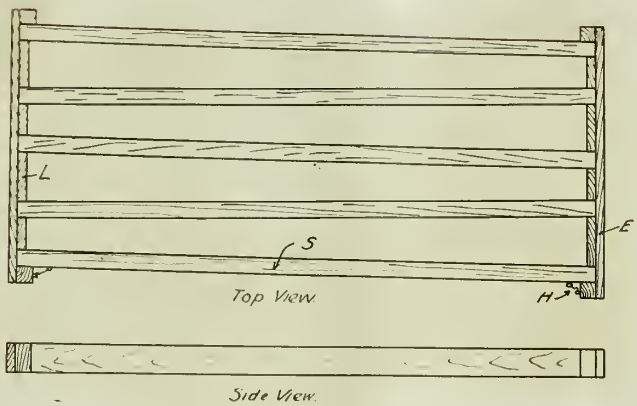


FIG 7.
POST MOLD

butt to top, while in Fig. 8 all the tops are necessarily at one end. Sharp corners of posts may be avoided by tacking triangular-shaped strips in the lower corners of the form and by using a trowel with a triangular tongue upon the concrete at the upper corners.

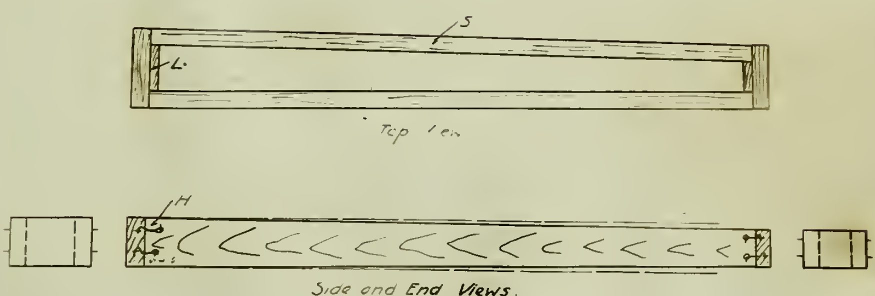


FIG. 8.
POST MOLD.

Fence posts are usually 6 to 7 feet in length with a rectangular base 5 to 6 inches square and a top 5 or 6 by 3 1/2 inches or 4 1/2 by 4 1/2 inches. Corner posts are made larger and with mortices for bracing.

Triangular Molds. The triangular form of post is also used. The molds are constructed along lines similar to those of the rectangular with a more substantial bracing of the siding. The usual dimensions are: base 7 inches and top 5 inches on a side.

Fasteners. There are several very good patented fasteners on the market,yet nearly any one can devise a satisfactory home-made article.

A convenient form consists of a 3 or 3 1/2-inch staple with one inch of each point turned back at right angles and away from each other. The loop of the staple projects from the post and to this,by means of a lighter wire,is attached the wire fence. Heavy wire may be used instead of the staple.

Wooden nailing pieces should never be inserted in posts as their expansion,due to moisture, cracks the concrete. Holes through a post weaken it.

The Molding. As the molds are usually bottomless,they must set upon a very smooth and level platform or floor. Oil or soap this floor in the same manner as the sides. Mix only sufficient concrete to fill the forms. Tamp the concrete into the first mold until there is a level layer 1 inch deep. Upon this layer place the reinforcing members 1 inch from the sides of the mold. Continue tamping in the concrete in thin layers (place fasteners at the proper depths) until the mold lacks 1 inch of being full. Place in the remainder of the reinforcing as before,fill the mold and level off and finish as desired.

The Curing. The outside boards of the molds may be removed after twenty-four hours, but the intermediate siding should remain two or three days. The post must not be disturbed for at least one and preferably two weeks. In the meantime they should be covered with sand, straw or saw dust, kept moist and protected from the sun and wind. Even after two weeks a very little careless handling will develop invisible cracks which may later result in failure. Posts should be placed on an even surface and allowed to cure two months before being used.

QUANTITIES OF MATERIALS.

In the computing of the quantities of materials needed for any structure Tables I, II, and III, pages 10 and 11 will be of considerable aid. Say that a farmer finds that his barn foundation will require 351 cubic feet or 13 cubic yards of concrete, and that he wishes to know the necessary quantities of cement, sand and broken stone with the dust screened out. Turning to kinds of mixtures under Table I, page 10, he ascertains that a MEDIUM MIXTURE, 1:2 1/2:5, is the best for such work. Foot Note 3, page 12, under Tables II and III, states that such broken stone usually runs 45% of voids. Turning to Table II, at the intersection of the 1:2 1/2:5 and the 45% columns, it is found that 5.2 sacks of cement, 0.46 cubic yards of sand and 0.92 cubic yards of stone are needed for 1 cubic yard of rammed concrete. Using this data, the concrete for the foundation will require:-

13 x 5.2 = 67.6 sacks of cement.

13 x 0.46 = 5.98 cubic yards of sand.

13 x 0.92 = 11.96 cubic yards of stone.

Should the farmer decide to use gravel, practically 351 cubic feet or 13 cubic yards will be required. According to the Foot

Note IV,page 12 under Tables II and III gravel generally has 40% of voids. Entering Table II with 40% of voids for a 1:2 1/2:5 mixture,one finds that 1 barrel (4 sacks) of cement will make 20.8 cubic feet of concrete. The amount of cement needed is shown by the following operation,351÷20.8 = 16.9 barrels or 67.5 sacks.

Caution. See Foot Note 1 under Tables II and III as to the variations in the above results; and remember that in these computations no allowance has been made for waste.

OTHER PLANS.

Many things not discussed in this thesis can be built of concrete. The author's reasons for not considering them are two-fold. Some are so easily constructed that they need no explanation; others are so difficult tnat they must be planned for each specific case. Among the things easily built are wind-mill foundations, chimney caps,horse blocks,hitching posts and small retaining walls--especially at the open ends of drains.

Whenever concrete is put in any considerable tension-that is, when the loading tends to stretch even one side of the structure--reinforcement of metal is necessary. The design of such work is the problem of the trained engineer,and the man not so qualified is foolish to attempt it. Such attempts usually result in unnecessary increase of cost or in total failure and probable loss of life. In concrete construction the very best ingredient is a fund of common sense.

APPENDIX.

DETERMINATION OF THE VOIDS.

Voids in Stone or Screened Gravel. The voids in the stone determine the necessary amount of sand. To ascertain the volume of the voids,fill a vessel of known capacity,say a candy bucket,with stone and tamp during the filling. Pour in water slowly at the side (or corner)of the vessel until it will hold no more. The quantity of water poured into the vessel indicates the quantity of sand needed to fill the voids between the pieces of stone. (Needless to say,in this test the stone must not be water-soaked nor so dry as to absorb water.) In practice,owing to the air bubbles in the stone,the amount of sand obtained as above is generally increased one tenth.

Voids in broken stone usually run 45 to 50% depending upon whether or not it is screened.

Voids in Sand. The voids in sand are determined as above. This determination fixes the required quantity of neat cement mortar, which is practically equal to the necessary amount of packed cement.

Voids in sand are generally equal to 33% of the volume.

Voids in Unscreened Gravel. Although it is almost generally acknowledged that better and less expensive results are obtained from screened gravel,nevertheless many persons persist in using it as it comes from the bank. The voids may be measured as for stone and this measurement indicates the amount of cement needed. Bank-run gravel should at least be tested occasionally to see

whether the sand and gravel are continuing in the proper proportions.

CORRECT PROPORTIONING.

Suppose that a vessel holds 5 gallons of packed crushed rock and at the same time will receive 2 1/4 gallons of water. Another vessel contains 3 gallons of packed sand and 9/10 of a gallon of water.

Increase by 1/10 the amount of water in the stone and the result is 2 1/2 gallons; therefore twice as much stone as sand is required. Add 1/10 to the water in the sand and the total is 1 gallon; therefore the cement needed is 1/3 the volume of the sand. This shows that the correct proportion for a concrete of the greatest density and strength is 1 : 3 : 6.

INDEX.

FARMERS' GUIDE IN CONCRETE CONSTRUCTION.